DEVELOPMENT OF A MONTHLY FIRE SEVERITY FORECAST

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ABSTRACT

An experimental fire severity forecast effort is described herein. Daily to monthly regional forecasts of near-surface fire-weather variables from the Scripps Experimental Climate Prediction Center experimental forecast system are being utilized for an experimental US Forest Service project concerned with predicting fire severity up to a month in advance. In particular, the severity forecast utilizes forecast estimates of fuel moisture content, drought and potential fire weather effects from temperature, relative humidity, cloud and precipitation variables. Efforts to reduce the forecast biases and evaluate the forecast skill for this complex system are underway.

Keywords: fire weather, fire danger, fire severity, forecasts

INTRODUCTION

In fiscal year 1998, the USDA Forest Service reported that approximately 770,000 hectares (1.9 million acres) of state and private lands burned in the preceding year. Total pre-suppression and suppression costs were a hefty $585 million. As large as that sum was, it was still less than the $830 million expended in the previous year. In times of ever increasing fiscal austerity, the Forest Service and other land agencies are anxious to find economic solutions to this vexing problem of fire management. One area that they hope for significant improvement is in strategic fire planning, especially in the process for allocating national resources for large fire contingencies. The Forest Service has always relied on its regional fire managers to assess the potential severity of the forthcoming fire season, and the ability of the local organization to respond under the expected conditions. Among the factors considered were the current state of fuels, staffing, and the expected weather. The primary tool which management used to assess the fire environment was the National Fire-Danger Rating System (Deeming et al. 1977), but it provided for short-term daily, not seasonal, rating of fire potential. The task of improving the current practice of seasonal severity forecasting was assigned to the Forest Service Fire Management Research, Development and Applications Program at Riverside, California. Working with the Fire Meteorology Research Unit at Riverside, the Fire Behavior Research Unit at Missoula, Montana, and the Experimental Climate Prediction Center (ECPC at La Jolla, California, the Fire Management Program has developed a methodology for assessing seasonal fire potential across the contiguous United States, which is only now being tested. This is the first study of its kind to address fire potential in a seasonal time frame, applying the relatively new technologies of climate and statistical modeling with the more familiar practice of fire-danger rating. This paper describes the seasonal severity forecasting process and its various modeling components.

MODELING STRATEGY

Previously, a monthly fire weather forecast was designed for national planning (Fujioka and McCutchan 1989; Fujioka 1990). The monthly forecast predicted the mean temperature, dew point, and precipitation frequency over a period of a month, but did not integrate fuels information. The Fire Management Program developers recognized early on that a good assessment of seasonal fire severity depended not only on obtaining as good a seasonal forecast as was possible of the fire weather trends, but also that weather and climate effects on wildland fuels, and hence fire potential, was also needed. The best means available to integrate weather and fuels information was the National Fire-Danger Rating System (NFDRS), which required a seasonal forecast of day to day weather changes.

A seasonal time frame was certainly not in the parameters of the original NFDRS design. But the spatial resolution of the NFDRS was consistent with the goals of the fire severity forecast, namely a broad area perspective of fire potential. We wanted the severity forecast to express the multidimensional assessment of fire potential that the NFDRS provides, i.e. spread and energy release characteristics (SC and ER), heavy fuel moisture content (TH, for thousand hour timelag fuel moisture), and a measure of drought effects (KB, for the Keetch-Byram Drought Index). The Burning Index (BI) was included, as a measure of flame length and fireline intensity. Finally, we selected a Fire Potential Index (FP) derived from the Normalized Difference Vegetation Index, routinely obtained from satellite imagery. The FP is an indicator of live fuel moisture content at spatial scales on the order of a kilometer, too fine a resolution for the purposes of this project.

We therefore aggregated the FP and other high-resolution data in square cells measuring 100 km on a side, from which we formed a grid covering the continental US. We obtained weather, fuels and fire data to populate the grid, and calculated the corresponding NFDRS indices. The fire data include number of fires on federal lands within each cell. If the cell has no federal lands, it is omitted from further consideration. A contractor derived spatial statistical models from this data to predict the expected number of fires within each cell, given the expected weather conditions (Fig. 1). The following section explains the modeling procedures to obtain the spatial statistical fire models and the predicted weather by week, for a 12-week season.

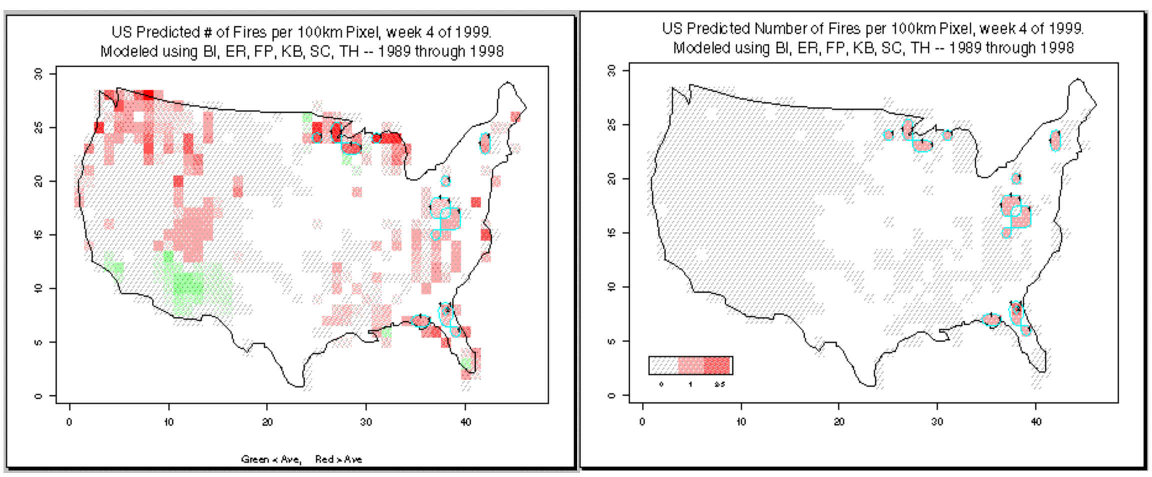

Figure 1. Examples of seasonal fire severity forecasts prepared from a) the integration of the global spectral model over four weeks, b) processing of weather and fuels data through the National Fire-Danger Rating System, and c) processing of fire indices through a statistical model that predicts number of fires.

PREDICTIVE MODELS

The models used to produce the seasonal severity forecast combine an empirical approach using regression methods, and a physics-based approach to predict the expected weather conditions.

Predicting Number of Fires

The predicted number of fires for each cell in Figure 1 was obtained by a weighted average of the number of fires by fuel model, given the time of year and the expected weather conditions. Given that cell ij has federal lands with a fire history represented in our data, and given the fuels and weather data to predict the aforementioned fire indices, represented by the vector {X_k}, we fit the statistical model:

$$\log(n_{ij} + 1) = \beta_0 + \sum_{k=1}^{6} \beta_k X_k \qquad \text{Eqn. 1}$$

where n_{ij} is the number of fires in cell ij, and the {$\_{k}$} are regression parameters determined by a least-squares fit of the data. We have also accounted for spatial autocorrelations of the indices at this point. Moreover, we examined the residuals of Eqn. 1 for the existence of spatial relationships.

Long-Range Weather Predictions

Long-range weather predictions were obtained from ECPC's atmospheric forecast system, which consists of two models. At the largest space and time scales, the modeling system uses the National Center for Environmental Prediction's (NCEP's) medium range forecast (MRF) model or global spectral model (GSM; Roads et al. 1999).

A high-resolution regional spectral model (RSM; Chen et al. 1999) is nested within the GSM, which provides initial and low spatial resolution model parameters as well as lateral boundary conditions for the RSM. The RSM then predicts regional variations influenced more by the higher resolution orography and other land distributions within a limited but high-resolution domain. All models use the same terrain following sigma layers and the same comprehensive set of physical parameterization modular packages, which include land surface parameters (e.g. soil wetness, soil temperature, etc.), sensible and latent heat fluxes, radiation fluxes, cloudiness, various three dimensional heating and moisture distributions, max/min temperatures, etc.

The forecast procedure is as follows. First, NCEP makes the global forecasts and posts the analysis and 4xdaily 72-hour forecasts on their ftp site. Due to bandwidth limitations of the Internet, only the complete initial conditions (operational analysis) and 72-hour forecasts 4 times daily (00, 06, 12, 18 UTC) for the global model are transferred. From these global initial conditions, the GSM is first integrated for 7 days, every day, and 90 days, every weekend. Initial SST anomalies are persisted throughout the integration.

After the first 7 global forecast days are completed, three regional domains (US, CA, SW), which use the forecast global fields as initial and boundary conditions, are integrated for 7 days. The global forecasts are then continued out to 12 weeks plus every weekend, while the regional forecasts are only continued out to 4 weeks every weekend. Even if the regional forecast accuracy merited more frequent or longer-range RSM forecasts, seasonal regional forecasts just cannot yet be done on a regular basis, due to lack of computer time. However, at least weekly 4-week RSM forecasts can now be made for the US domain. In particular, every week, the ECPC makes 4-week RSM forecasts of daily (2pm) temperature, relative humidity, cloud amount, wind speed, as well as minimum and maximum temperature and relative humidity, precipitation amount and frequency. These forecasts are linearly interpolated to the 100-km fireweather grid described above and incorporated into the various NFDRS indices.

This forecast system has a number of biases that need to be accounted for and removed (Roads et al. 1998). For example, in some places the RSM has a cold bias and a consistent excessive relative humidity. Precipitation can be too high or too low, depending upon the region. Cloudiness biases are unknown but are thought to be large. Correcting these errors will be critical for eventually developing a useful predictive ability of fire severity.

SUMMARY AND CONCLUSIONS

Although this is not the first effort at predicting fire severity for the contiguous United States, we believe this is the first attempt that combines the sciences of fire-danger rating, seasonal weather forecasting, and spatial statistics.

We began with the NFDRS fundamental parameterizations, because they integrate the terrain, fuel and weather factors that bear significantly on fire potential. We incorporated weekly daily forecasts out to a month from the ECPC GSM and RSM numerical models. These models provide the weather information needed to calculate the fire indices that make up the fire severity forecast. We then used various statistical models, since statistical models are currently the most practical means of predicting fire severity (number of fires) from causative factors. Recognizing that there would likely be spatial association in the independent variables, we also included a spatial analysis component in the statistics.

We wound up with a highly complex modeling system that we are just beginning to evaluate and much work remains in verifying the effectiveness of this modeling approach. We are also faced with the challenge of making this system acceptable within the community of fire managers for which it is intended. We did not begin this project thinking that it would be easy and we have not been disappointed in that regard.

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